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**Methods for identifying or diagnosing carcinoma cells with metastatic potential based on the measurement of lymphoid genes or their products in carcinoma cells**

This application is a continuation-in-part of U.S. patent application serial no. 08/680,372, filed July 15, 1996, which is a divisional of U.S. patent application serial no. 08/118,969, filed September 9, 1993 (now U.S. patent 5,536,642).

**1.0 FIELD OF THE INVENTION**

The present invention relates to methods for distinguishing human solid non-lymphoid tumor cells with lymphotropic metastatic potential from those without this property and for treatment thereof.

**2.0 BACKGROUND OF THE INVENTION**

**2.1. Metastasis**

Metastasis or the spread of primary tumor cells to a secondary organ is a complex process involving a cascade of steps (Paget, S., 1889, *Lancet*, 1:571-573, Fidler, I.J., 1990, *Cancer Res.* 50:6130-6138). Neoplastic transformation usually results in the dedifferentiation of pre-malignant cells. Consequently, there is a loss of cell-to-cell adhesiveness and a detachment of tumor cells from the primary tumor bed. However, detachment does not ensure the spread of primary tumor cells to distant sites, since tumor cells must also acquire migratory capability to invade a secondary organ (Fidler, I.J., Kripke, M.L., 1977, *Science* 197:893-895.). More specifically, tumor cells must have target specific motility and preferential chemotaxis to direct them toward either blood vessels (hematogenous metastasis) or lymphatics (lymphotropic metastasis) (Willis, R.A. 1972. 3rd Edit. London: Butterworth). It is our hypothesis that primary tumor cells may become metastatic by acquiring the phenotypic properties of migrating T lymphocytes. Once they acquire this invasive phenotype, these T cell "like" solid tumor cells can either be swiftly carried away by blood flow or may roll through lymphatic channels (Imhof, B.A., Dunon, D., 1995, *Adv. Immunol.* 58:345-416). Migration of tumor cells is promoted by specific receptor/ligand interactions between the tumor cells and cells lining the endothelium of secondary sites (Weiss et al., 1988, *FASEB J.* 2:12-21; McCarthy et al., 1991, *Sem. Cancer Biol.* 2:155-167) where arrest and adhesion of tumor cells occurs. Here the tumor cells may die, become dormant, or invade the organ's parenchyma where they proliferate and undergo homeotypic aggregation (Yefenof et al., 1993, *Proc. Natl. Acad. Sci.* 90:1829-33; Cohen et al., 1995, In: NK Cells in the Liver, Bouwens L, ed. RG Landes Biomedical Publication, Austin, CRC Press. Pp. 71-100). Tumor cells use growth factors produced by the tumors themselves (autocrine) or by cells from the secondary organs (paracrine) for colony growth and survival (Radinsky, R., 1992, *Cancer Metas. Rev.* 12:345-361).

In accordance with this specification and claims, tumor cells may be classified as benign if they have not invaded surrounding tissue and malignant if they ~~do~~ have done so, and malignant tumor cells may be classified as having metastatic potential if they have the capacity to spread through the lymph or blood systems to distant sites and to have non-metastatic potential if they do not have such capacity. If metastatic cells have the capacity to spread through the lymph system, they are defined herein and in the claims as having "lymphotropic" metastatic potential. A "primary" tumor is defined, for the purpose of this specification and the claims as one which is located at its site of origin, i.e., before any metastasis thereof, as contrasted with a "secondary" tumor, which is a tumor located at a site to which the primary tumor has metastasized.

Metastasis presents a cancer clinician with great difficulty in diagnosing and treating the

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malignant tumor because (i) metastasis may comprise as little as one or a few cells thereby evading clinical diagnosis even with modern techniques; (ii) often metastasis has already been seeded by the time a patient is diagnosed with a malignant non-lymphoid solid tumor (Silverberg et al., 1989, *CA Cancer J. Clin.* 39:3-21); (iii) treatment is more complex than simple surgical excision of the primary tumor; (iv) systemic therapy for metastatic non-lymphoid solid tumors, such as renal cell carcinoma (Rosenberg et al. 1985, *N. Engl. J. Med.* 313:1485-1492) remains ineffective with little survival advantage; and (v) not all malignant tumors have the same metastatic potential and no direct relationship has been established in determining whether any particular carcinoma will develop metastasis.

Monoclonal antibodies (Mab) have been used to characterize and classify T cell surface molecules such as the clusters of differentiation (CD) of human leukocyte antigens. As illustrated in Fig. 1, the T cell receptor (TCR), illustrated at 20, is an integral membrane protein, expressed on the surface of T lymphocytes, illustrated at 22, occurring as a disulfide linked heterodimer that is non-covalently associated with CD3 chains, illustrated at 24. TCR has been linked to autoimmune disease and anti-TCR antibodies have shown therapeutic potential for treating autoimmune disease (Basi et al., 1992, *J. Immunol. Meth.* 155:175-191). In some cancers, a correlation exists between an increase in concentration of the TCR associated CD8 molecule in the serum of children with non-Hodgkins lymphoma and the stage of the disease and its responsiveness to therapy (see U.S. Pat. No. 5,006,459).

Several studies have shown that T cell-associated molecules (Omar et al. 1991, *AIDS* 5:275-281, Kawami et al., 1993, *Biotherapy* 6:33-39; McMillan et al. 1995, *Int. J. Cancer* 60:766-772) are expressed on the surface of non-lymphoid solid human tumor cells. SW620, a metastatic human colon tumor-derived from the lymph node of a 51-year-old male has been shown to possess the TCR co-receptor CD4 on its surface by several different methods including Northern analysis and FACS (Omary et al 1991, *AIDS* 5:275-281). To date, no one has directly identified V $\beta$  sequences on the surface of carcinoma cells.

### 3.0 SUMMARY OF THE INVENTION.

The present invention is related to our belief that the acquisition of lymphotropic metastatic potential by such transformed cells is accompanied by their ability to express aberrant lymphoid specific genes or their products including germline CT $\beta$ , germline V $\beta$  and their related TCR associated genes or their products and TCR associated signal transduction genes or their products. More specifically, the determination of the percentage of cells of a solid non-lymphoid tumor expressing lymphoid gene products including, but not limited to, the following three categories of closely related lymphoid specific genes or their products: Category 1, (germline CT $\beta$ , germline V $\beta$  variants); Category 2 (TCR associated molecules; CD3e, CD4, CD7, CD8) and Category 3 (T cell-derived signal transduction molecules; CD3 $\zeta$ , p56 type 1, p59 type T, ZAP-70, and SYK) is used, in accordance with the present invention, to identify lymphotropic metastatic potential. As used herein and in the claims, the term "lymphoid gene products" is meant to include the lymphoid genes as well as the products thereof.

Accordingly, an object of the invention is to predict the lymphotropic metastatic potential of a solid non-lymphoid tumor.

Another object of the present invention is to provide treatment for such a tumor.

In order to predict the lymphotropic metastatic potential of a solid non-lymphoid tumor, in accordance with the present invention, a plurality of representative samples of the tumor are obtained and the percentage of cells in each of the samples which express lymphoid gene products is determined, wherein the metastatic potential of the tumor is predicted to be low when

a low percentage of tumor cells in all of the samples are detected to express lymphoid gene products and predicted to be high when a high percentage of tumor cells in at least one of the samples are detected to express lymphoid gene products.

In order to predict the lymphotropic metastatic potential of a primary solid non-lymphoid tumor, in accordance with the present invention, cells from the tumor are injected sub-cutaneously into at least one anti-AsGMI-treated (NK depleted) nude animal (such as a nude mouse) and the animal examined for tumors at sites other than the site of the injection.

In order to treat a solid non-lymphoid tumor, in accordance with the present invention, a substance comprising a therapeutically effective amount of a molecule linked to a toxin, radionuclide, or chemotherapeutic agent and having binding specificity for a tumor-specific lymphoid gene product idiotype is systemically administered.

The above and other objects, features, and advantages of the present invention will be apparent in the following detailed description of the preferred embodiment thereof when read in conjunction with the accompanying drawings wherein the same reference numerals denote the same or similar parts throughout the several views.

#### 4.0 BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a schematic view of the structure of TCR $\alpha/\beta$ .

Fig. 2 is a view similar to that of Fig. 1 of the predicted surface expression of germline CT $\beta$  and V $\beta$  on non-lymphoid solid tumor cells (surface orientation of V $\beta$  unknown).

Fig. 3 is a view of the PCR analysis of MCA-26 tumor cells and Balb/c thymus cDNA. Primers V $\beta$ 8: sense primer in the variable region and CT $\beta$ -A1: anti-sense primer in the constant region, separated by 200-230 bp in the intact TCR $\beta$  transcript of thymus cells, were used to determine rearrangement of the 1.0 kb transcript in the colon tumor cell line, MCA-26. The thymus band of roughly 427 bp indicates the presence of a normally oriented single TCR  $\beta$  transcript containing both V $\beta$ 8 and CT $\beta$  mRNA. Note that the lack of such a band in the MCA-26 lane reflects the lack of a similar single TCR  $\beta$  transcript in MCA-26 cDNA. Lane 1: 100 bp ladder, Lane 2: cDNA from MCA-26 tumor cells (band at 366 kb), Lane 3: cDNA from Balb/c thymus (band at 427kb), and Lane 4: actin cDNA control (band at 544 kb).

Fig. 4 is an immunofluorescence view of MCA-26 tumor cells with: A) FI- anti-mouse Ig control, B) FI-anti-mouse V  $\alpha$ 3, C) FI-anti-mouse TCR $\beta$ , and D) FI-anti-mouse V $\beta$ 8.1/2 antibody.

Fig 5 is a graph illustrating proliferation of  $10^4$  Balb/c peritoneal macrophages (PM);  $5 \times 10^4$  MCA-26 tumor cells in serum free medium control; (1 $\mu$ g/ml) SEB; SEB + anti-mouse V $\beta$ 8.1/2.1/2 (azide free); SEB + PM; SEB + PM + anti-mouse V $\beta$ 8.1/2; SEB + PM; SEB + PM + anti-mouse V $\beta$ 8.1/2 antibody. Cells were cultured in a 96-well plate for 72 h and pulsed with 1  $\mu$ Ci of 3H-Tdr for 6 h, harvested and cpm counted.

Fig. 6a is a view of local growth and lymph node metastasis of SMT-2A rat breast tumor cells after sc injection in W/F rats.

Fig. 6b is a view of SMT-2A tumor cells stained with FI-anti-rat CD8.

Fig. 7 is a graph showing growth kinetics of metastatic SW480E colon tumor cells vs. growth of nonmetastatic SW480R colon tumor cells after sc injection of  $2 \times 10^6$  tumor cells in athymic nude mice.

Fig. 8 is a graph showing growth kinetics of metastatic SW480E colon tumor cells after sc injection of  $2 \times 10^6$  tumor cells into continuously treated anti-AsGM1 nude mice or discontinuously (at day 30) treated anti-AsGM1 nude mice, and further showing that tumor growth declines when anti-AsGM1 treatment is ceased on day 30.

Fig. 9 is a view of a Northern blot analysis of human tumor cell line RNA. Human tumor cell lines were grown in 100 mm tissue culture dishes containing RPMI 1640 media supplemented with 10% FBS and 50 µg Gentamicin until semi-confluent. Total RNA was extracted, resolved through agarose, and hybridized to the 400 bp consensus sequence of the constant region of the human T cell receptor β (400bp CTβ probe). Poly-A mRNA was either purchased or obtained by passage of total RNA across a poly-T column. Blots were re-probed with TPI. The motility of rearranged intact TCRβ is roughly 1.3 kb in functional mature T cells. Lane 1: poly A mRNA from the MOLT-4 cell line, Lane 2: poly A mRNA from SW480, Lane 3: poly A mRNA from Raji, Lane 4: poly A mRNA from the colon tumor derived cell line COLO205, Lane 5: total RNA from SW620, Lane 6: total RNA from Jurkat cells, Lane 7: total RNA the from colon tumor derived cell line HT29.

Fig. 10 is a line graph illustrating the percent of SW620 mRNA hybridizing to the 400bp consensus sequence probe, extracted from cells exposed to culture medium containing 2% DMSO from 0 to 9 days compared to SW620 mRNA extracted from cells not exposed to DMSO over this period. Band intensities were determined using a Phosphorimager (Molecular Diagnostics, Sunnyvale CA) and normalized to the housekeeping gene Triose Phosphate Isomerase.

Fig. 11 is a view of determination of rearrangement of the TCRβ gene in human tumor cell lines. Southern blot analysis of genomic DNA digested with the restriction endonuclease Hind III, separated over a 0.8% agarose gel, and probed with the <sup>32</sup>P random primer labeled consensus sequence for the constant region of the TCRβ gene (400bpCβ probe). Each lane contained twenty µg of genomic DNA. Rearrangement disrupts the usual 7.7, 3.7 kb banding pattern seen in Hind III CTβ probed unrearranged genomic DNA. Lane 1: Raji (B cell line that does not undergo TCR rearrangement), Lane 2: control Molt-4 (T-cell Leukemia that does undergo TCR gene rearrangement), Lane 3: SW480, Lane 4: SW620, Lane 5: COLO205, Lane 6: HT-29.

Fig. 12 is a view of FACS analysis using FITC-labeled anti-Vβ 3 (JOVI-3), anti CTβ (JOVI-1), or anti-CD4 (Q4210). FACS analysis was performed on 1X10<sup>6</sup> cells as described in the methods section. Graphs are relative cell number (counts) versus relative fluorescence per cell (FL1-H).

Fig. 13 is a view of determination of cell surface expression of CTβ or Vβ3 peptides by direct immuno-fluorescent staining of 0.5X10<sup>6</sup> cells with FITC-labeled anti-CTβ (JOVI-1), anti-Vβ3 (JOVI-3), or control (rabbit anti-mouse IgG).

Fig. 14 is a view of PCR analysis of human peripheral blood leukocyte (HuPBL) and SW620 cDNA. Primers Vβ-3S1: sense primer in the variable region and CTβ-A1: anti-sense primer in the constant region, separated by 200-230 bp in the intact TCRβ transcript of mature T cells, were used to determine rearrangement of the 1.0kb transcript in the colon tumor cell line SW620. The HuPBL band of roughly 230 bp indicates the presence of a normally oriented single TCR β transcript containing both Vβ3 and CTβ mRNA. Note that the lack of such a band in the SW620 lane reflects the lack of a similar single TCR β transcript in SW620 cDNA. Lane 1: SW620 cDNA, Lane 2: cDNA from human peripheral blood leukocytes, Lane Ld.: 0.1kb ladder.

Fig. 15 is a view of PCR analysis of cDNA from colon tumor cell lines using paired internal Vβ3S1 primers (Vβ3NS1 and Vβ3NAS1, 150bp); lanes 1-4, and CTβ primers (CTβS1 and CTβAS1, 290bp); lanes 5-8. The cDNA was obtained from purchased or constructed libraries with reported genomic contamination of less than 1%. The amplified products exhibited by the SW480 and SW620 cDNA's indicate presence of CTβ and V β mRNA as single transcripts. Lane Ld: 0.1kb ladder. Lane 1 and 5: HuPBL, Lane 2 and 6: SW620, Lane 3 and 7: SW480, Lane 4 and 8: Colo 205 cell lines.

Fig. 16 is a view of DNA sequences of PCR products generated in figure 15 from human

colon tumor cell line and peripheral blood leukocyte cDNA using (A) CT $\beta$  primers (CT $\beta$ S1 and CT $\beta$ AS1, 290bp) and (B) V $\beta$ 3S1 primers (V $\beta$ NS4 and V $\beta$ NAS4, 153bp). Sequences represent cDNA amplified between but not including primers. Asterisk (\*) denotes base deviation of human colon tumor PCR products from that of peripheral blood leukocytes.

Fig. 17A is a view of a western blot of SYK (anti-human SYK) from Lane 1: Jurkat; Lane 2: SW480; Lane 3: SW480E; Lane 4: SW480R and Lane 5: SW620 cell lines. SYK is 72 kDa. Note presence of the 70 kDa isoform of SYK in SW480E cells.

Fig. 17B is a view of a western blot of SYK (anti-human SYK) from Lane 1: Jurkat; Lane 2: SW480E.

Fig. 18 is a view of a western blot of ZAP-70 (anti-human ZAP-70) from Lane 1: Jurkat; Lane 2: SW480; Lane 3: SW480E; Lane 4: SW480R and Lane 5: SW620 cell lines. ZAP-70 is 70 kDa.

Fig. 19 is a graph showing the effect of plate bound anti-human V $\beta$ 3 on proliferation of SW620 tumor cell lines. One  $\times 10^4$  SW620 cells were culture with various concentrations of anti-V $\beta$ 3. Tumor cells were cultured in a 96-well plate for 72 h and pulsed with 1  $\mu$ Ci of 3H-Tdr for 6 h, harvested and cpm counted.

Fig. 20 is a graph showing the effect of human IL-16 on proliferation of SW620 tumor cell lines. One  $\times 10^6$  SW620 tumor cells were culture with various concentrations of human IL-16. Tumor cells were cultured in a 24-well plates for 48 h and number of cell counted with a Coulter Counter.

Fig. 21 is a view of immunocytochemical and fluorescence photomicrograph analysis of TdT, CD3 and  $\beta$ F1 on stage II and stage III human breast ductal carcinoma cells in two woman. A) Tumor cell imprints made from 18 mm primary tumor of a 44-year old woman (MB/87-4906) with multiple axillary lymph node metastases (15 positive lymph nodes out of 21) show many TdT-positive cells as demonstrated by PAP procedure. These cells were also positive for CD3e and  $\beta$ F1 (anti-CT  $\beta$ ). B) Metastatic tumor cells from an enlarged axillary lymph node of a 82-year old woman (EN/88-279) (three massive metastatic axillary lymph nodes) ho had a large primary tumor (50 mm diameter) fixed to the chest wall, showed scattered TdT-positive cells as demonstrated by the indirect immunofluorescence procedure. Metastatic tumor cells from the second patient (EN/88-279) expressed C) CD3e and D)  $\beta$ F1 (anti-CT  $\beta$ ) (X800). **There was no significant difference in the number and intensity of CT $\beta$  and other T cell associated molecules between primary and metastatic tumors in these breast cancer patients.**

Fig. 22 is a view of FACS and fluorescence photomicrograph analysis of CD3/CD45 on Stage II breast cancer cells in a 75-year old woman.

## 5.0. DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

### 5.0.1. Expression of germline CT $\beta$ , germline V $\beta$ genes and related T cell associated molecules on carcinoma cells.

Fig. 2 illustrates at 30 a tumor cell wherein germline or unrearranged V $\beta$  gene and C $\beta$  transcripts, illustrated at 32 and 34 respectively, are expressed on the tumor cell surface, as discussed in greater detail hereinafter. Other lymphoid gene products may also be expressed on the tumor cell surface. Since very few somatic mutations are found in T cell clones or T cell lines, V $\beta$  may be an excellent target for diagnosis and immunotherapy. In this regard, V $\beta$ 6 positive syngeneic T cell tumors can be inhibited from growing by administering anti-mouse V $\beta$ 6 to mice (Kanagawa et al., 1989, *J. Exp. Med.* 170:1513-1521).

Interestingly, the anti-tumor treatment of mice bearing T cell tumors by anti-V $\beta$  antibody does not compromise the immun status of the mouse despite the fact that a significant proportion of peripheral T cells are eliminated by the treatment. In another study, one-third of V $\beta$  chains were genetically deleted in certain mouse strains causing a deficit in the expressed repertoire of TCR without jeopardizing immune potential (Kanagawa et al. 1989, *J. Exp. Med.* 170:1513-1521). Since the number of genes encoding known V $\beta$  segment is limited, the epitopes expressed on a V $\beta$  gene product from normal cells can be used as a target molecule for monoclonal antibody diagnosis and therapy of solid tumors expressing V $\beta$  chains. Further, there is a bias for certain V $\beta$  genes. V $\beta$  is dispersed throughout the gene locus and represents a wide range of post selection utilization, from abundantly expressed V $\beta$ 8 to those that are rarely expressed such as V $\beta$ 5. Selected expression would not be expected in the precursor population before surface expression of V $\beta$ . It would seem reasonable to establish panels of antibodies specific for each V $\beta$  gene segment for use in diagnosis and therapy of carcinomas expressing clonally distributed germline V $\beta$  genes.

#### **5.0.2. Ability of lymphoid genes to convert primary nonmetastatic tumors into potentially metastatic tumors. Three possible mechanisms of conversion (Fusion, derepression or emperiopolesis).**

Normally, epithelial cells including primary neoplastic cells do not migrate. However, there are cells in the body whose function is to migrate to distant organs. These migrating cells are members of the immune system and include immature or pre-T bone marrow cells, immature or pre-T thymocytes, T cells, B cells and macrophages and others. Without wishing to be bound by theory here or elsewhere in this application, we believe that the lymphoid specific genes from these migrating cells can convert or allow the progression of nonmetastatic carcinoma cells into potentially metastatic carcinoma cells. There are at least three mechanisms by which this may phenomena occur. Kim et al. (1993, *Proc. Am. Assoc. Cancer Res.* 34:63A) have successfully converted primary nonmetastatic non-lymphoid mammary rat tumor cells (NM-081) into metastatic tumor cells (NMT-2) that carry TCR associated molecules by fusing them with thymocytes (Table 1). These "converted" metastatic NMT-2 mammary tumor cells can metastasize to the lymph nodes of mice. The nonmetastatic NM-081 mammary tumor cells do not express T cell associated markers while the metastatic NM-T2 cells express CD8 and Thy 1 on their surface. On the other hand, NM-081 fused with macrophages converted these mammary tumor cells into metastatic cells (NM-M2) that metastasized to the lungs.

Conversely, expression of lymphoid genes in tumor cells may arise from derepression, as proposed by Helmericks and Rosen. Helmericks and Rosen (1995, *J. Biol. Chem.* 270:27538-27543) have shown that 35 kDa and 75 kDa repressive molecules bind to the 5' promoter region (-520 to -460 kb) of the p56<sup>lck</sup> gene and inhibit the expression of this T cell-associated signal transduction molecule in human colon cancer cell lines such as HT-29, T84 and Hela cells. In contrast, when these repressive molecules are absent (i.e., COLO205 colon tumor cells), the tumor cells can express the p56<sup>lck</sup> type 1 (thymocyte) gene product. In another study, McCracken et al (*Oncogene*, 1997, 15:2929-2937) demonstrated that p56<sup>lck</sup> type 1 promoter in Hela cells could be activated when the tumor cells were transfected with ETS-1 and Sox-4 transcription factors.

Finally, there have been reports that lymphoid cells can penetrate the cytoplasm of tumor cells where they remain viable (Radosevic et al. 1995, *Cytometry* 20:273-278). This process has been termed emperiopolesis. Emperiopolesis of lymphocytes in tumor cells has

also been observed Tsunoda et al. 1992, *Virchows Archiv* 62:69-74). Although which mechanisms actually causes conversion of nonmetastatic carcinoma cells to T cell "like" carcinoma cells are unknown, we believe that the outcome is the same. i. e., the lymphoid gene program can convert epithelial nonmetastatic carcinoma cells into metastatic carcinomas. Additionally, these three mechanisms are not necessarily mutually exclusive (Mayer et al., 1993, *Int. J. Oncol.* 3:366-372). Further, it should be possible to "read" the lymphoid program expressed on the non-lymphoid T cell "like" solid tumor cell surface and predict, (i) whether the tumor cells are potentially metastatic, (ii) the number of potentially metastatic tumor cells in the primary bed and (iii) the secondary site or sites where the tumor cells may travel. It appears that tumor cells expressing lymphoid properties travel to the lymph nodes via the lymphatics while tumor cells expressing macrophage properties go to the lungs via the blood stream ( see Table 1).

Lymphoid cells and metastatic tumors migrate preferentially to certain organs and even prometastatic territories (zones) within the same organ. For example, colon tumors tend to metastasize to the lymph nodes and liver, breast tumors to the lymph nodes and prostate cancer to the bones. Infiltrating T lymphocytes involved in hepatitis and metastasizing colon tumor cells are arrested in the periportal region or zone 1 of the liver lobule (Vidal-Vanaclocha et al. 1993, *Sem. Liver Disease* 13:60-67). More important, cancer cells arrested in zone 1 of the liver lobule remain and develop metastatic foci while tumor cells that migrate to the pericentral region or zone 3 do not form colonies (Barbera-Guillem. et al. 1989, *Cancer Res.* 49: 4003-4010.). Similarly, infiltrating CD4<sup>+</sup> T cells remain in zone 1 while CD8<sup>+</sup> T cells redistribute throughout the organ (Cohen S.A. et al. 1996. In: *Natural Killer Cells in the Liver*, ed. Bouwens L, RG Landes Biomedical Publishers, Austin, CRC Press. pp. 71-100.). These CD4<sup>+</sup> T cells resemble hematopoietic colony forming cells that also only develop colonies in zone 1. When metastatic tumor cells and colony forming cells are simultaneously arrested in zone 1, augmented growth of both cell populations occurs (Vidal-Vanaclocha et al. *Int. J. Cancer* 46:267-271) suggesting that these cell types share and respond to common ligands and growth factors using similar or identical receptors. Colon and breast carcinoma tumor cells can express CD4 on their surface. It has been demonstrated that CD4<sup>+</sup> T cells with a phenotype that was CXCR4<sup>+</sup>, CD26<sup>-</sup>, CD45R0<sup>-</sup> and CD45RA<sup>+</sup> tend to migrate to lymph nodes while T cells with a phenotype that was CCR5<sup>+</sup>, CD26<sup>+</sup>, CD45R0<sup>+</sup> and CD45RA<sup>-</sup> migrate to peripheral tissue (Bleul et al. 1997, *Proc Natl Acad. Sci.* 94:1925-1930). CD4 bearing metastatic tumors would contain addresses that would preferentially direct them to zone one of the liver and lymph nodes. Thus, metastatic tumor cells are "piggybacked" to the site and masked behind a T cell "like" cover. The concept that migrating cells contain molecular addresses on their surface that can be read by molecules at their destination sites has been previously discussed (Rusoslahti E., 1996, *Sci. American* 275:72-77; Springer T.A., 1994, *Cell* 76:301-314).

The following examples in Sections 5.1.0 through 5.1.3 demonstrate the detection of germline CTβ, germline Vβ and their related T cell-associated molecules on/in human and experimental tumors using one or more methods selected from the group consisting of fluorescence microscopy, fluorescence activated cell sorting (FACS), ELISA, ELISPOT, Western blot analysis, enzymatic amplification, nucleic acid sequencing. The human tumor cell lines were obtained as follows: Jurkats, SW480, SW620, BT474 (ATCC, Bethesda, MD). Vβ3 expressing C7CH17 cells were obtained from the Imperial Cancer Center (London, England). SW480E and SW480R were supplied by Dr. I. B. Weinstein (Columbia University, NY, NY). The rat tumor cell lines and human biopsies were supplied by Dr. U. Kim (Buffalo,



NY). All tumor cell lines were grown in plastic T-flasks in a humid atmosphere of 5% CO<sub>2</sub> in air, in adequate media supplemented with 10% FBS and containing penicillin and streptomycin. Anti-JOV1 and anti-JOV3 were obtained from Ancell Corp. of Baysid Minnessota.

**5.1.0. Insuring Lymphocyte-free Tumor cells for Testing.** In order to insure that no lymphocytes or other leukocytes were in the samples tested as described herein, tumor cell lines, which are known to be devoid of lymphocytes or other leukocytes, were used, except that, where clinical samples were used, as in the Table 7 tests, FITC-labeled anti-EMA (anti-epithelial membrane antigen) antibody tumor marker was used to locate only the tumor cells to insure that products of lymphocytes or other leukocytes were not included in the assay. Other ways to prepare pure tumor cell populations (without lymphocytes or other leukocytes) include mixing Dynabeads magnetic beads coupled with anti-EMA antibody with the tumor cell suspension, as discussed in Latza et al, *J. Clin. Path.* 43:213-218, and in Naume et al, *J. Hematother.* 6:103-114 (1997). Cell viability is not affected by process and is suitable for immunocytochemical, PCR and RT-PCR analysis. Other antibodies may also be substituted such as (for Colorectal Cancer) HEA125 MAb, HT29-15 MAb; (for Breast Cancer) EMA MAb, B72.3 MAb, BCD-B4MAb, NCRC-11 MAb; (for Prostate Cancer) anti-PSA antibody, PD41MAb and; (for Lung Cancer) ALT-04 MAb.

**5.1.1. Enzymatic amplification of carcinoma cell mRNA.** The tumor biopsies or surgical specimens discussed hereafter were obtained, purified as above to insure that no lymphocytes or other leukocytes were included in the assays. Tumor cells were detached by brief exposure to 0.1% Trypsin plus 2mM EDTA, then incubated for 48 hours in spinner-flask in media plus 10% FBS at 5%CO<sub>2</sub>. After extraction and quantification of the mRNA (shown to be intact by 0.7% agarose gel electrophoresis), a total of 20 µg of purified RNA was separated on a 1.2% agarose gel containing 22 M formaldehyde. The electrophoresis was performed at 80V. The tracks containing the molecular size standard was cut off the gels and the migration distances were measured. The gels were rinsed and transferred onto nitrocellulose filter. Expression of Vβ mRNA can be detected by extracting and purifying mRNA from nonolymphoid tumor cells and then subjecting the purified mRNA to enzymatic amplification to obtain sufficient quantities for analysis and detection. Enzymatic amplification techniques which could be employed include those known in the art such as PCR (polymerase chain reaction) and nucleic acid sequence-based amplification. Detection of the amplified nucleic acid includes techniques known in the art including, but not limited to, agarose gel electrophoresis and Northern blotting. Fluorescence-based hybridization assays; chemiluminescence-based hybridization assays, and captures hybridization microtiter assays. Oligonucleotides primers and probes can be synthesized from the nucleic acid sequence of the Vβ's. Probes can be synthesized with methods known to those skilled in the art to incorporate either non-isotopic or isotopic label. Alternatively, the label may be incorporated directly into the amplified product. In this example, single-stranded cDNA, obtained by reverse transcription from the extracted tumor cell mRNA, was amplified by PCR<sup>TM</sup> utilizing primers for Vβ genes from commercial sources. The amplified products were separated on a 1.2% agarose gels and stained with ethidium bromide in parallel with positive and negative controls.

**5.1.2. Confocal Immunofluorescence microscopy or FACS of lymphoid gene products from carcinoma cells.** Tumor biopsies or surgical specimens, purified as discussed above, were isolated and prepared for confocal Immunofluorescence microscopy or for FACS. After



being washed, the carcinoma cells were incubated for 30 minutes at 4° C. in a solution of PBS, fixed with 1% paraformaldehyde, and analyzed within 48 hours using confocal microscopy or FACS. Quantitative analysis of V $\beta$  expression and other markers on tumor cells was performed using either of these methods.

**5.1.3. Western-blot for carcinoma-derived T cell signal transduction molecules.** Tumor biopsies or surgical specimens purified as discussed above, were isolated and tumor cell lysates were prepared for Western analysis. For analysis 5x10<sup>6</sup> tumor cells or control cells were collected into PBS containing 1 mM PMSE. After washing, cells were homogenized in buffer 10 mM Tris-HCl pH 7.4, containing 0.25 M sucrose, 1 mM MgCl<sub>2</sub>, 5 mM CaCl<sub>2</sub>, and a mixture of protease inhibitors. Polyacrylamide gel electrophoresis was performed. The protein was transferred onto nitrocellulose filters by electrophoretic transfer for 2 hours at 40 V. The filter was then incubated in avidin blocking solution with 3% normal human serum, following three washes with TTBS. The mouse anti-human antibodies (CD3 $\zeta$ , p56, p59, ZAP-70, SYK) added at a 1:40 dilution in TTBS and incubated for 2 hours. After three washes, a biotinylated rabbit-anti mouse IgG was added at a 1:200 dilution in TTBS for 1 hour. Following three washes with TTBS, the blot was incubated with avidin and biotinylated horseradish peroxidase for 30 minutes. The blot was then incubated with DAB and the sites of antibody binding were revealed by brown precipitate. The molecular weight (MW) marker proteins were: beta-galactosidase (116 Kd), Bovine albumin (66 Kd), Egg albumin (45 Kd) and carbonic anhydrase (29 Kd).

## **5.2.0 EVIDENCE FOR PRESENCE OF GERMLINE CT $\beta$ and V $\beta$ ON MURINE COLON ADENOCARCINOMA CELL LINES.**

**5.2.1. Northern analysis of CT $\beta$  message expression in murine adenocarcinoma tumor cell lines.** Murine MCA-26 colon tumor cells, MCA-38 colon tumor cells and B16F10 melanoma cells were cultured, RNA extracted and tested for mRNA using a human CT $\beta$  probe (see below). RNA from ConA activated splenic T cells gave a normal 1.35 and truncated 1.0 kb message for CT $\beta$ . In contrast, the murine tumors gave a 1.1 kb message consistent with a truncated CT $\beta$  message (not shown). Davis (1990, *Ann Rev Biochem* 59:475-496.) has shown that a truncated 1.0 kb message is found on non-tumor cells.

**5.2.2. RT-PCR analysis of V $\beta$ 8 message expression in MCA-26 tumor cells.** Murine colon MCA-26 cells were cultured, RNA extracted and tested for V $\beta$ 8 mRNA using the appropriate primers for V $\beta$ 8, and CT $\beta$  (see Candeias et al. 1994, *Eur J Immunol.* 24:3073-3081 for primer sequences). As shown in Fig. 3, RNA from Balb/c thymocytes gave a band at 427 kb consistent with a rearranged V $\beta$ 8 message. In contrast, RNA from MCA-26 colon tumor cells gave a band at 366 kb that was consistent with an unrearranged germline V $\beta$ 8 message.

**5.2.3. Germline V $\beta$  and related molecules on the surface of murine colon adenocarcinoma cell lines; ligation of tumor-derived germline V $\beta$ 8 by SEB/APC.** Using immunofluorescence, we have observed V $\beta$ 8.1/8.2 and TCR $\alpha\beta$  on the surface of murine MCA-26 colon tumor cells (Fig. 4). In contrast, the tumor cells were not stained for the isotype control and V $\alpha$ 3. SEB is a superantigen that can bind to the V $\beta$  chain on the T cell receptor and trigger these cells to divide (Lamphear et al., 1998, *J. Immunol.* 160:615-623). MCA-26 colon tumor cells expressing a putative V $\beta$ 8 receptor, were stimulated in serum free conditions

with peritoneal macrophages pulsed with SEB, and the tumor cells underwent increased proliferation (Fig. 5). The proliferation of the stimulated tumor cells was blocked by the addition of azide free anti-V $\beta$ 8.1/8.2 suggesting that tumor-derived germline V $\beta$  could be ligated by the superantigen, SEB to induce a transduction signal through the V $\beta$  chain. Similar results were observed with MCA-38 colon tumor cells. Table 2 is a summary of results demonstrating the expression of TCR $\beta$  and other lymphoid gene products on the surface of various murine carcinoma cell lines. The more metastatic the tumor cells the higher expression of TCR $\beta$  on their surface.

### **5.3.0 EXPRESSION OF VARIOUS LYMPHOID MARKERS ON NONMETASTATIC AND METASTATIC RAT MAMMARY ADENOCARCINOMA CELL LINES.**

**5.3.1 Development of rat mammary adenocarcinoma cell lines.** We have developed a panel of seven syngeneic rat mammary tumor cell lines that progress from estrogen dependent to independent over a 20-year period (Table 3A). These tumor cell lines were in different states of differentiation. Interestingly, the least differentiated (MTW9B, MTW9C, MTW9D) were not metastatic while the metastatic tumors (MT449, MT450) were among the most differentiated. These primary rat mammary tumor cell lines (MT449, MT450) were capable of invading the lymph nodes as well as other organs. More important, only the metastatic tumor cell lines expressed either of the lymphoid gene products; CD4 or CD8 (Table 3A and 3B).

**5.3.2 Metastatic rat mammary tumor cells are rejected by nude mice while nonmetastatic tumorigenic rat mammary tumors grow in nude mice.** Some human tumors can be successfully xenografted in athymic nude mice after growing them *in vitro*, but they seldom metastasize (Fogh et al. 1982, In:Proceedings of the 3<sup>rd</sup> International Workshop on Nude mice, Gustav Fisher, NY, pp. 447-456; Kim et al. 1984, In:Proceedings of the 4th International Workshop on Immune-deficient animals, S. Karger, Basel, , pp. 235-238). The nonmetastatic MT-100 rat breast tumor after subcutaneous injection form local tumors in Wistar/Furth (W/F) rats and athymic nude mice (not shown). In contrast, the metastatic rat TMT-081 rat breast tumor after subcutaneous injection formed local tumor and metastasized to the lymph nodes in W/F rats but did not form tumors in nude mice (not shown). When these same nude mice were treated with anti- lymphocytic serum (ALS), the TMT-081 tumor began to grow and metastasize. If anti-ALS treatment was discontinued, the tumor ceased growing and began to scar. Thus, a lymphocyte population prevented the growth of metastatic tumors in nude mice when continuously present. In another series of experiments, nonmetastatic MT-W9B rat breast tumors grew locally in nude after sc injection. However, the metastatic SMT-2A rat breast tumors did not grow in nude mice (not shown). However, these tumors grew locally and metastasized in syngeneic W/F rats (Fig. 6A). Further, these metastatic rat tumor cells expressed CD8 on their cell surface (Fig. 6B).

### **5.4.0. EXPRESSION OF VARIOUS LYMPHOID MARKERS ON NONMETASTATIC AND METASTATIC HUMAN CARCINOMA CELL LINES.**

**5.4.1. Tumorigenic and metastatic properties of SW480E and SW480R colon carcinoma cells in nude and anti-AsGM1 treated nude mice.** SW480, is a primary Dukes

C colon carcinoma cell line derived from a 50-year-old male patient. One year later, the same patient developed lymph node metastasis. SW620 is the cell line derived from that lymph node lesion. Two lines from SW480, were cloned namely; SW480E and SW480R tumor cells (Tomita et al., 1993, *Cancer Res* 52:6840-6847). The properties of the primary tumor, the two subclones, and the lymph node metastasis are listed in Table 4. When SW480R cells were injected subcutaneously into nude mice without NK depletion, a large local tumor grew but no metastasis was detected. In contrast, SW480E cells gave little local growth and were not metastatic (Fig. 7).

The SW480E cells were motile *in vitro*. In contrast, SW480R cells proliferated more than SW480E *in vitro* but were much less motile *in vitro*. Since nude mice contain highly efficient NK cells (Cohen et al. 1990, *Cancer Res* 50:1820-1828), this is believed to mean that these potentially metastatic SW480E cells are NK sensitive. Therefore, when nude mice were treated with anti-AsGM1 to abrogate their NK cells, these SW480E tumor cells not only grew locally (Fig. 8) but also metastasized to the lymph nodes. The withdrawal of anti-AsGM1 treatment on day 30 led to the cessation of tumor growth, as shown in Fig. 8.

**5.4.2. Expression of the CT $\beta$  message in a panel human carcinoma cell lines.** Using a 400-bp consensus sequence for the constant region of TCR  $\beta$  (CT $\beta$ ), extracts of total RNA from a panel of human tumor cell lines were analyzed by Northern blots. Fig. 9 revealed the presence of the 1.0 kb CT $\beta$  chain message in some tumor cell lines examined. SW480 tumor cells expressed less of this message than SW620 cells. The metastatic subclone, SW480E cells expressed more CT $\beta$  message than the tumorigenic, nonmetastatic subclone, SW480R cells (not shown). Other human tumor cell lines; T84, LS174T, A549, T47D, Hela, HepG2 cell lines tested for the CT $\beta$  message were negative (not shown). SW948, a cell line from a grade III colon adenocarcinoma was positive for the CT $\beta$  message. In contrast, other human colon tumor cell lines; COLO201, COLO205, COLO320 and DLD-1 were negative for CT $\beta$  mRNA (not shown).

**5.4.3. Effect of differentiation of lymph node-derived SW620 colon tumor cells on expression of tumor-derived CT $\beta$  mRNA.** When SW620 tumor cells were incubated in 2% DMSO, there was loss of tumor-derived CD4, as discussed in Omary et al. (1991, *AIDS* 5:275-281). DMSO caused SW620 cells to undergo differentiation in which the morphology was changed from round (R) to epitheloid (E) and tumorigenicity was suppressed as discussed in Omary et al. (1993, *J. Cell Biochem.* 48:316-323). To determine if differentiation could alter the expression of the TCR $\beta$  message, SW620 cells were cultured with 2% DMSO for up to eight days. The cells were harvested at various times, RNA extracted and analyzed for CT $\beta$  message. As shown in Fig. 10, differentiation of the SW620 tumor cells results in a dramatic decrease in the level of the CT $\beta$  message when compared to untreated control tumor cells.

**5.4.4. CT $\beta$  genes from SW480 colon tumor cells do not undergo rearrangement.** In T cell precursors, the  $\beta$  chain is synthesized before the  $\alpha$  chain and then gene rearrangement occurs (Mallick et al., 1993, *Cell* 73:513-519). However, CT $\beta$  can be transcribed directly from DNA in a germline form (Candeias, S. et al. 1994, *Eur. J. Immunol.* 24:3073-3081). Therefore, a Southern blot analysis was performed to determine if rearrangement occurred in the tumor cell lines expressing the 1.0 kb CT $\beta$  transcript. Fig. 11 shows that genomic DNA from the Raji cells, SW480 tumor cells and T47D breast tumor cells do not undergo rearrangement and result in fragment sizes of 7.7 kDa, 3.7 kDa for CT $\beta$  when cut by the restriction enzymes *Hind* III. As control, MOLT4 cell line, a T cell derived leukemia that undergoes rearrangement, resulted in altered bands. Similar conclusions were drawn from Southern blots when DNA was cut by

*Eco*R1 or *Bam*H2 (data not shown).

**5.4.5. Surface expression of CT $\beta$  on SW480, SW480E, SW480R and SW620 colon adenocarcinoma cell lines.** To determine if the CT $\beta$  1.0 kb message recognized by the cDNA probe could be translated to express a surface bound CT $\beta$  gene product, FACS analysis was carried out (Fig. 12) using FITC mouse anti-human CT $\beta$  (JOVI-1). This antibody reacts with 50-75% of T cells from control normal human peripheral blood cells (HuPBL) as shown in Viney et al. (1992, *Hybridoma* 11:701-713). SW480 and SW620 cells were surface stained for this antibody that recognizes the human CT $\beta$ 1 gene product. Anti- $\beta$ F1 which also recognizes the CT $\beta$ 1 gene product gave the same result (not shown). However, FITC-anti-TCR $\alpha$  ( $\alpha$ F1) and FITC-anti-TCR $\delta$  ( $\delta$ TCS1) did not stain the metastatic SW620 tumor cell line. The SW480 cell line showed a similar pattern (not shown). As a control, the T cell leukemia cell line, MOLT 4, was CT $\beta$ <sup>+</sup> while the B lymphoblast cell line RAJI was CT $\beta$ <sup>-</sup>. To confirm the presence of CT $\beta$  on SW480 tumor cells and SW620 tumor cells immunofluorescence (Fig. 13) was performed. Both of these tumor cell lines expressed surface bound CT $\beta$ .

**5.4.6. Expression of a germline V $\beta$ 3 message on a panel of human colon adenocarcinoma cell lines.** To determine if the V $\beta$ 3 found in Fig. 13 is derived from a rearranged transcript, PCR analysis of SW620 and HuPBL cDNA was completed using a V $\beta$ 3 (sense) and Ct $\beta$  (anti-sense) primers. As shown in Fig. 14, a 230-kb band was present suggesting a recombined V $\beta$ 3 was present in the HuPBL control cDNA library. In contrast, the recombined transcript was not present in a SW480 cDNA library when probed with the same primers. Since SW620 colon tumor cells bind the superantigen, SEB, a molecule known to interact with V $\beta$  of the TCR $\beta$  (Dohlstein, 1991, *Eur. J. Immunol.* 21:1229-1237), we determined whether the V $\beta$  transcript was present on these cells. SEB binds to a limited number of V $\beta$ 's including V $\beta$ 3, V $\beta$ 12, V $\beta$ 17 and V $\beta$ 20 (Scherer et al. 1993, *Ann. Rev. Cell Biol.* 9:101-28). To determine the presence of V $\beta$ 3 in solid tumor cells, we made internal primers from a V $\beta$ 3 sequence present in the cloned T cell line; PL4.4 (Accession No. L36092). These primers were used to identify rearranged and germline V $\beta$ 3 from various cDNA libraries by PCR. As shown Fig. 15, germline V $\beta$ 3 and CT $\beta$  were present in cDNA libraries made from SW480 and SW620 colon tumor cell lines. V $\beta$ 3 but not CT $\beta$  was present in the cDNA library from COLO205 cells. In contrast, the colon tumor cell line, HT-29 did not transcribe either V $\beta$ 3 or Ct $\beta$  (not shown). The PCR products, 50 and 230 kb bands were isolated and sequenced. As shown in Fig. 16A, the CT $\beta$  nucleotide sequences from the HuPBL, SW480 and SW620 cDNA libraries were 100% homologous. COLO205 and HT-29 (not shown) did not express the CT $\beta$  transcript. In addition, V $\beta$ 3 nucleotide sequences from the HuPBL, Colo205, SW480 and SW620 cDNA libraries were 99% homologous (Fig. 16B).

**5.4.7. Surface analysis of V $\beta$  expression on human carcinoma cell lines.** SW620 tumor cells can be a target for CD8 human effector cells through a superantigen dependent cellular cytotoxic mechanism (Dohlstein et al. 1991, *Eur J Immunol.* 21:1229-1237). Since SW620 cells do not express HLA-DR, it is likely that SEB binds and forms a bridge between surface bound germline V $\beta$  on these colon tumor cells and HLA-DR on T cells to cause lysis of the <sup>51</sup>Cr-SW620 target cells. Recent evidence has shown that germline V $\beta$  can be directly transcribed and expressed on the surface of thymocytes and bone marrow cells (Oneill HC. 1995, *Immunogenetics* 42:309-314; Jolly CJ., 1995, *Inter. Immunol.* 7:1147-1156; Jolly CJ. Oneill HC., 1997., *Immunol. Cell Biol.* 75:13-20). We, therefore, assayed for the presence of V $\beta$ 3 and CD4 molecules on the surface of these carcinoma cell lines on SW480 and SW620 cells. As shown by FACS in Fig. 12 and by

immuno-fluorescence in Fig. 13, both SW480 and SW620 tumor cells expressed V $\beta$ 3 while only SW620 expressed CD4.

**5.4.8. Expression of T cell-derived signal transduction molecules in carcinoma cell lines (possible role in metastasis).** Jurkat cells, SW480, SW480E, SW480R and SW620 tumor cells were cultured and lysates prepared and tested for the presence of signal transduction molecules. These molecules are found almost exclusively in T cells. The cell lysates were blotted and probed with anti-human SYK, ZAP-70, CD3 $\zeta$ , p56<sup>lck</sup>, p59<sup>fyn</sup>. The SYK family of nonreceptor protein-tyrosine kinases comprises two members; SYK and ZAP-70 (van Oers et al. 1995, *Seminars Oncol.* 7:227-236). ZAP-70 is found exclusively in T cells and NK cells whereas SYK accumulates in most hematopoietic cells including B cells, bone marrow cells and immature T cells. As shown in Fig. 17, the 72 kDa SYK is present in Jurkat, SW480, SW480R and SW620 cells. Interestingly, SW480E cells possess both the 72 kDa immunoreactive product of SYK and a 70-kDa isoform of the protein (SYKB). It has been shown (Latour et al, 1996, *J Biol Chem* 271:22782-2290) that an isoform of SYK-B exists that is missing 23 AA in its "linker" region. Both isoforms have been shown to be present in bone marrow cells but not T cells. The function of the lower molecular weight form is unknown. In contrast, ZAP-70 (Fig. 18) was present in high amounts in SW480E cells while little or none was detected in SW480 parental cells. Further, none was observed in SW480R or SW620 cells. Why SW480E cells are the only tumor that contains ZAP-70 and both isoforms of SYK is unknown. Both SYK and ZAP-70 are crucial for hematopoietic development. The lack of ZAP-70 leads to abnormal T cell maturation while the lack of SYK reduces B cell development, hemostasis and maturation of  $\gamma\delta$  T cells. Thus ZAP-70 and SYK-B may be essential in enabling SW480E cells to be motile and invade.

Table 5 summarizes the expression of lymphoid-derived signal transduction molecules on these carcinoma cell lines. CD3 $\zeta$  which is essential in coupling the TCR to ZAP-70 was present in all tumors tested. p59<sup>fyn</sup> was expressed on all tumor cell lines. In contrast, p56<sup>lck</sup> was only detected in SW480R and SW620 cells.

**5.4.9. Effect of anti-V $\beta$ 3 or IL-16 on proliferation of SW620 cells *in vitro*.** Experiments were carried out to determine whether V $\beta$ 3 and CD4 on the surface of SW620 cells could be ligated with the appropriate signal. As shown in Fig. 19, plate-bound anti-V $\beta$ 3 induced SW620 tumor cells to proliferate in serum free media. Plate-bound anti-V $\beta$ 3 augmented the proliferation of (V $\beta$ 3<sup>+</sup> transfected) C7CH17 cells (Viney et al. 1992, *Hybridoma* 11:701-713). It is known that IL-16 can bind to its receptor, CD4 and ligate it (Centers et al. 1996, *Immunol. Today* 17:476-481). Fig. 20 demonstrates that the addition of IL-16 to CD4 bearing tumor SW620 cells augmented the proliferation of these tumor cells in serum free media. Thus, these two experiments indicate that tumor-derived T cell receptors are functional and therefore may be manipulated for therapy.

## 6.0 EXPRESSION OF VARIOUS LYMPHOID MARKERS ON NONMETASTATIC AND METASTATIC HUMAN CANCER CELLS FROM CLINICAL SAMPLES OF PATIENTS WITH COLON AND BREAST CANCER.

The expression of lymphoid gene products was determined on biopsy samples from breast and colon cancer patients. As shown in Fig. 21A, two patients with stage II and stage III human breast ductal carcinoma cells were investigated for expression of surface T cell markers. A tumor cell imprint made from 18 mm primary tumor of a 44-year old woman (MB/87-4906) with multiple axillary lymph node metastases who had 15 positive lymph nodes out of 21 show many TdT-positive cells as demonstrated by PAP procedure. These primary tumor cells were also positive

for CD3e and  $\beta$ F1 (anti-CT $\beta$ ) as shown in Table 6. Metastatic tumor cells from an enlarged axillary lymph node of a 82-year old woman (EN/88-279) with three massive metastatic axillary lymph nodes with a large primary tumor (50 mm diameter) fixed to the chest wall, showed scattered TdT-positive cells as demonstrated by the indirect immunofluorescence procedure (Fig. 21B). Metastatic tumor cells from this patient, also expressed CD3e (Fig. 21C) and  $\beta$ F1 (Fig. 21D). Table 6 also shows that the primary tumor was positive for CD3e, CD8 and CT $\beta$ . There was no significant difference in the number or intensity of T-cell antigen-positive cells between primary and metastatic tumors in these patients. Fig. 22 shows a tumor sample from a 75-year old stage II breast cancer patient. 88% of this patient's tumor cells were CD3 positive (Fig. 22A). These samples are also positive for epithelial membrane antigen (EMA) as shown in Fig. 22B. A further survey was carried out with 20 more breast cancer patients (Table 6). As shown in the Table, stage 1 human breast cancers that do not have regional lymph node involvement (NO) also do not express T cell associated surface molecules including  $\beta$ F1 (anti-CT $\beta$ ), CD3e, CD4, CD8 and TdT. In contrast, clinical samples from patients with primary breast tumors and up to three lymph nodes involved (N1-N3) expressed  $\beta$ F1, CD3e, CD4, CD8 and TdT lymphocyte surface antigens. Table 7 and Table 8 contain data from additional clinical samples from breast and colon cancer patients that demonstrated the expression of Lymphoid gene products on primary and metastatic tumors.

## 7.0 CLINICAL APPLICATIONS OF THE MEASUREMENT OF TUMOR-DERIVED GERMLINE V $\beta$ AND RELATED LYMPHOID GENE PRODUCTS IN PRIMARY LESIONS (COLON, BREAST, PROSTATE) AND IN THEIR METASTASIS (LIVER, LYMPH NODES).

**7.1. Determining a metastasis prognosis.** Because of the problems that metastases present in terms of diagnosis and treatment of carcinomas, a method for determining a metastasis prognosis is desirable. One embodiment for metastasis prognosis comprises the following steps:

- i) Obtain samples of the primary tumor (presurgical or intrasurgical biopsy), suspect lymph nodes, liver and serum samples;
- ii) Use tissue slices or anti-epithelial antibody coupled to magnetic beads or other means to separate to obtain pure tumor cells.
- iii) Obtain tumor cell suspensions and poly A mRNA from each sample.
- iv) Establish the presence of lymphoid gene products in each tumor samples using PCR and the appropriate primers. These assays have the advantage of being very sensitive. The assay will measure the presence of all germline V $\beta$ 's, germline CT $\beta$  (JOVI-1,  $\beta$  F1), TdT, CD3e, CD4, CD7, CD8, CD3 $\zeta$ , p59<sup>lyn</sup>, p56<sup>lck</sup>, ZAP-70, SYK, SKYB (70 kDa isoform) and EMA (for epithelial cells)
- v.) Once established which transcripts are present, determine whether their products are present on the cell surface or intracellularly expressed (for signal transduction molecule) using FACS, immunofluorescence and western blotting. From this data, the probability of metastasis from primary tumor cells determined.
- vi) To help verify the above determinations, functional tests for tumorigenicity and metastasis may be carried out by injecting the patient's tumor cells sub-cutaneously into anti-AsGM1(NK depleted) nude mice (or other nude animals) and, after a suitable period of time, examine the mice for local growth and lymph node and bone marrow metastasis. They may also be injected into control nude mice. **Interpretation of results:** As previously discussed, tumorigenic/NK resistant tumor cells grow only locally in nude mice after subcutaneous injection. Metastatic/NK sensitive tumor cells are rejected by nude mice but grow locally and metastasize in anti-AsGM1(NK depleted) nude mice. See Figs. 7 and 8.

In order to obtain a sufficiently reliable prediction of metastatic potential, several

representative samples should be obtained from different locations throughout the tumor mass since the tumor mass may not be homogeneous. The term "representative samples", as used herein and in the claims, is therefore meant to include a sufficient number of tumor sections taken from various locations including center and peripheral regions throughout the tumor mass to be assured that the prediction of metastatic potential based thereon is reliable. If no tumor cells in any of the representative samples are detected to express lymphoid gene products, then the metastatic potential of the tumor may be predicted to be low (if not zero). If a high percentage of tumor cells in any one of the representative samples are detected to express lymphoid gene products, then the metastatic potential of the tumor may be predicted to be high. While in practice grades may be assigned for various percentages of tumor cells expressing lymphoid gene products, as little as 2 to 5 percent of the tumor cells in a single representative sample expressing lymphoid gene products may be considered to be a high percentage. See, for example, case 15 in table 7 wherein 30% of the cells of SCH89-23P were EMA-positive meaning that 30% of the cells of this sample were tumor cells, and of these 6% expressed CD4 and 19% expressed CD7, yet this tumor was metastatic. The suffixes "P" and "M" in the tumor identifications in this and the other tables indicate primary and secondary (samples taken from sites to which the primary tumors had metastasized) tumors respectively. A tumor identification without such a suffix indicate a primary tumor, and either no metastasis was found or not looked for, but it couldn't be said that the tumor did not eventually metastasize. For other examples, see table 8, cases 9 to 12. The percentages of lymphoid gene products in tables 7 and 8 are the percentages of the tumor cells located in the sample. CD3, CD4, CD8, CT, and V are considered to be the more critical lymphoid gene products because they are part of the TCR receptor complex and therefore recognize antigen in context with MAC-1 and/or MAC-2. The other lymphoid gene products are considered less critical to the analysis.

**7.2. Assays to be used in the diagnosis and treatment of metastatic disease.** The enzymatic amplification of tumor cell RNA may be used to measure the expression of message in the tumor samples. The fluorescence microscopy, FACS, Elispot and western blotting may be used to measure specific proteins in the tumor sample.

### 7.3. Theoretical staging of metastasis based on lymphoid gene products expressed on carcinoma cells

Tumor Site	Stage	Vβ	CTβ	CD4	p56	ZAP-70	SYK72	SYKB	IL-2R
<b>Primary</b>									
Noninvasive tumor cells	1	-	-	-	-	-	-	-	-
Tumor cells with invasive potential	2	+	+	-	-	-	+	-	-
Metastatic tumor cells that	3	++	++	+	-	+++	+++	+++	-
<b>Secondary (distant)</b>									
Tumor cells that have invaded and colonize	4	+++	+++	++	+	-	+	-	+

Without being bound by theory here or elsewhere in this application, we theorize the following model of lymph node metastasis. Normal colon cells transform into preneoplastic and then neoplastic cells. These later tumor cells maintain their colonic surface properties (**Stage 1**). However, a few of these colonic tumor cells have either i) their lymphoid genes derepressed or ii) fuse with one or more populations of hematopoietic pre-T cells to form tumor cells with invasive potential (i.e., SW480 cells, **Stage 2**). The SW480 colon tumor cells contain two populations



(SW480R and SW480E) that express lymphoid genes and their proteins. These cells are not invasive since tumorigenic SW480R cells suppress the metastatic SW480E cells. Many of the surface and signal transduction molecules in the parental SW480 population are downregulated (i.e., V $\beta$ , CT $\beta$ , CD4, p56<sup>lck</sup>, SYK72, SYKB, ZAP-70) compared to isolated SW480E cells. It is likely that the SW480R cells produce anti-inflammatory cytokines (IL-4, IL-10, TGF $\beta$ ) that suppress various TCR and related molecules on SW480E cells. Thus, SW480E cells may not normally migrate in the presence of SW480R cells. Oreilly et al. (1996, *Nature, Medicine* 2:689-692) have shown that large primary tumor masses can prevent metastasis by producing substances (angiostatin) that stop the growth of new blood vessels in distant organs. The removal of the primary tumor may suppress angiostatin and allow the few remaining tumor cells to metastasize.

Since metastatic cells have unstable membranes, SW480E cells may shed MHC-1. The loss of MHC-1 makes SW480E cells vulnerable to apoptosis and NK cells. IL-16 produced by endogenous CD8<sup>+</sup> cells binds to CD4 on the SW480E cell surface, augments p56 type 1 expression and induces ZAP-70 expression resulting in metastatic tumor cells that will invade (Stage 3). The few SW480E cells that survive NK lysis may enter the lymphatic system, and travel to the lymph nodes. Metastatic SW480E cells require ZAP-70 and SYKB but not the IL-2R to migrate. When the SW480E tumor cells are arrested in the lymph nodes, they are converted into SW620 tumor cell phenotype under endothelial control and begin to express high levels of IL-2R, TCR $\beta$ , V $\beta$ , CD4, and p56 (Stage 4). These SW620 cells undergo clonal expansion and homeotypic aggregation when triggered by endogenous IL-2 and IL-16. The SW480E cells that remain become dormant since they do not express IL-2R or migrate without ZAP-70 expression. Thus the IL-2R is necessary for colonization but not migration. This theory suggests that the expression of lymphoid gene products on tumor cells results in a propensity for metastatic dissemination to distant sites in the same way that migrating T cells expressing the same antigens progress to their target.

**7.4 Treatment of a solid non-lymphoid tumor.** In accordance with the present invention, a substance comprising a therapeutically effective amount of a molecule linked to a suitable conventional toxin, radionuclide, or chemotherapeutic agent and having binding specificity for a tumor specific lymphoid gene product idotype is systemically administered. This molecule may, for example, be an anti-ZAP-70 or anti-SYK-B antibody or a cell permeable ZAP-70 antagonist, as discussed hereinafter.

**7.5 Inhibition of tumor-derived ZAP-70 to prevent metastasis.** Ligation of the V $\beta$  chain of TCR $\beta$  and CD4 to the nonpolymorphic regions of MHC-II colocalizes V $\beta$  and CD4. CD4 is also directly associated with the T cell signaling molecule, p56 type 1 (thymus-derived). This colocalization activates tyrosine kinases (p56) and causes a rapid cascade of intercellular signaling events. The activation of the tyrosine kinases (p56, SYK, ZAP-70) leads to phosphorylation of CD3 $\zeta$ . ZAP-70 is necessary for the phosphorylation of signaling enzymes such as inositol phospholipid hydrolysis, increases in intercellular Ca<sup>++</sup>, PKC and ultimately regulate transcriptional factors for DNA binding and gene activation or suppression. We also believe that ZAP-70 is intimately involved in tumor cell migration since it is only present in the metastatic SW480E cells. Therefore, in order to treat a solid non-lymphoid tumor, in accordance with the present invention, ZAP-70 is blocked to inhibit its phosphorylation or kinase activity and thereby inhibit metastasis by use of a cell permeable nonpeptide ZAP-70 antagonist such as, for example, a compound developed by Novartis Pharma Ltd of Switzerland and described in Revesz et al, 1997, *Bioorganic and Med Chem Letters*. 7:2875-2878, and by other means.

The tables referred to herein are appended hereto.

Although the invention has been described in detail herein, it should be understood that the invention can be embodied otherwise without departing from the principles thereof, and such other embodiments are meant to come within the scope of the present invention as defined by the appended claims.

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**Table 1 Ability of nonmetastatic (NM081) rat mammary tumor cells to fuse with thymocytes or macrophages and converted into lymph node (NM-T2) or lung (NM-M2) derived metastatic cells<sup>1</sup>**

Cells	Differentiation State	Metastasis Site	CD3	CD8	Mac-1
NM081 tumor cells	+++	-	-	-	-
NM-T2 (NM081 + thymocytes)	+	Lymph Node	+	+	-
NM-M2 (NM081 + macrophages)	+	Lung	-	-	+
thymocytes	-	-	+	+	-
macrophages	-	-	-	-	+

<sup>1</sup>Nonmetastatic NM081 rat mammary tumor cells were fused with thymocytes or peritoneal macrophages by standard methods and the hybrid tumor cells phenotyped for CD3, CD8 or Mac-1 or injected subcutaneously into syngeneic rats and metastasis determined.

Note: the greater the number of +s is correlated to the degree of the respective property, and a - indicates that the respective property is not present or is negative.

**Table 2 Expression of lymphoid markers on murine nonlymphoid tumor cells**

Marker	Met->	Melanoma B16F10	Colon Carcinoma		51B	51B110	Mammary Carcinoma	
		H	MCA-26 H	MCA-38 H	L	H	MC4908 L	MC7849 H
Vβ8		++	++	++	ND	ND	ND	ND
TCRαβ		++	++	++	+	++	+	++
TCRγδ		-	-	-	-	-	-	-
Thy1.2		+++	+++	+++	ND	ND	+++	ND
CD3ε		±	±	±	-	±	-	±
CD4		+	+	+	+	+	+	+
CD5		ND	++	ND	ND	ND	ND	ND
CD8		-	-	-	-	-	-	-
CD44		++	++	++	++	++	++	++
IL-2Rα		+++	+++	+++	ND	ND	+	+++
NK1.1		-	-	-	-	-	ND	ND
MAC-1		ND	-	ND	ND	ND	ND	ND

Met=Metastatic potential; [H] high; [L] low

Direct immunofluorescence staining [+++] highly positive cells; [++] mostly positive cells; [+] some positive cells; [-] negative cells; [ND] not done

Table 3 Properties of breast cancer cell lines derived from Wistar Furth rats

Tumor	differentiation state	estrogen receptor	CD4	CD8	metastatic site
A.					
Nonmetastasizing					
MT-W9	++	+	-	-	-
MTW9A	+++	++	-	-	-
MTW9B	+	+	-	-	-
MTW9C	+	-	-	-	-
MTW9D	+	-	-	-	-
Lymphogenous and hematogenous metastasizing					
MT449	++	-	+	-	LN, lung
MT450	+++	±	+	-	LN, lung, liver, brain
B.					
Nonmetastasizing					
MT-100	+	ND	-	-	-
Lymphogenous metastasizing					
SMT-2A	+	ND	-	+	LN, bone
Lymphogenous and hematogenous metastasizing					
TMT-081	+	ND	+	-	LN, lung, spleen

Note: the greater the number of +s is correlated to the degree of the respective property, and a - indicates that the respective property is not present or is negative.

**Table 4 Tumorigenicity and Metastatic Potential of Human Colon Tumor Cell Lines**

Property	SW480	SW480E	SW480R	SW620
Morphology	E+R	E	R	R
Dominance in Cell Fusion		-	+	
Adhesiveness		Good	Poor	
Growth Characteristics		Monolayer	Pile-up	
Doubling Time		32h	15h	
NK sensitivity		+++	-	
MHC-1 expression	+	+	+++	+++
Motility <i>in vitro</i>		+++	-	
Tumorigenicity in vivo (SC: local growth in nude)		-	++++	
Lymph node Metastasis (SC:LN mets in non NK depleted nude)		-	-	
Lymph Node Metastasis (SC:LN mets in NK depleted nude)		+++	-	
Immunogenic		-	+	
Shedding of TAA		+	-	

E=epitheloid

R=round

Note: the greater the number of +s is correlated to the degree of the respective property, and a - indicates that the respective property is not present or is negative.

**Table 5 Expression of T cell derived signal transduction molecules in colon tumor cell lines<sup>1</sup>.**

Property	Jurkat	SW480	SW480E	SW480R	SW620
CD3ζ	+	+	+	+	+
p56 type 1	+	-	-	++	++
p59	+	+	+	+	+
ZAP-70	+	+	+++++	-	-
SYK72	+	+	++	+	+
SYK70	-	-	++	-	-

<sup>1</sup>Determined by western blotting

Note: the greater the number of +s is correlated to the degree of staining, and a ± denotes borderline staining, and a - indicates no staining.



**Table 6 T-cell associate molecules in fresh human breast cancer cells by immuno cytochemistry**

Patient I.D. code	Age status	TNM	TdT	CD3	T-cell markers CT $\beta$	CD8	CD4
<b>Stage I</b>							
LD/88-730	32	T1NO	-	-	-	-	-
MA/DMH-1349	38	T1NO	-	-	-	-	-
JF/87-5056	45	T2NO	-	-	-	-	-
NP/87-8803	49	T1NO	-	-	-	-	-
SM/87-7843	50	T1NO	-	-	-	-	-
TG/88-1506	56	T1NO	-	-	-	-	-
BK/88-1791	56	T1NO	-	-	-	-	-
JS/SCH-3483	62	T2NO	-	-	-	+	±
IN/88-997	62	T1NO	-	-	-	-	-
IA/88-1677	63	T1NO	-	-	-	-	-
D0/87-5124	69	T1NO	±	-	-	-	-
IT/88-734	73	T2NO	++	-	-	-	-
AD/88-2004	79	T1NO	-	-	-	-	-
<b>Stage II and III</b>							
KS/88-1526	34	T1N2	-	++	+++	++	+
MB/87-4906 <sup>1</sup>	44	T2N2	+++	+	++	-	-
SW/88-2794	44	T2N1	+	+	+	+	++
LJ/88-1010	52	T3N3	-	+++	+	-	-
BR/87-4991	55	T2N1	++	±	±	±	±
LC/88-2055	57	T2N1	-	++	++	+	++
EN/88-279 <sup>2</sup>	82	T1N2	++	++	++	++	-

T1=stage 1; T2=stage 2; T3=stage 3 -

N=0; no lymph node involvement

N=1; 1 lymph node involved

N=2; 2 lymph nodes involved

TdT is Terminal Deoxynucleotidyl Transferase

CT $\beta$  is  $\beta$ F1 (T cell Sciences) and is directed to the CT $\beta$  chain of human TCR

<sup>1</sup>see Figure 21

<sup>2</sup>see Figure 21

Note: the greater the number of +s is correlated to the degree of staining, and a ± denotes borderline staining, and a - indicates no staining.

**Table 7 Flow Cytometric Analysis Of Fresh Human Breast Cancer Cells for the Expression of T-cell Associated Molecules**

Case No.	CD3	CD4	CD8	CD14	CD45	CD7	Leu-8	EMA
1. S89-5825	1%		1%	5%	1%			
2. S89-5827	2	1	2		3			
3. S89-5938P		89	2	1	1	2		
S89-5938M	5	2	1		5			
4. S89-6280	1	1	1	2	10			
5. S89-6296M		55	43	29	13	28		
6. S89-6508		6	5	20		36		
T, 257 S89-6756P		25	16	11	10	42	32	
S89-6756M		12	0	0	2	55	12	
8. S89-6923		71				42	51	
9. S89-7153		7	3	3	5	9	3	51
10. S89-7239	14			2	29			21
11. S89-7396	71	60	4	54	54			52
12. DM89-4435		10	6	1	2	11		56
13. DM89-4462		11	8	5	4	17		46
14. SCH22-M		49	15	6		24		
15. SCH89-23P		6	1	0	0	19	11	30
SCH89-23M	19	9	5		39	10		20
16. S90-686M		14	0		2	23		

FACSscan histograms on this analysis and direct immunocytochemistry of unsorted cell smear.

**Table 8 Flow Cytometric Analysis of Human Colorectal Cancer Cells for the Expression of T-cell Associated Molecules.**

Case No.	CD3	CD4	CD8	T cell markers			Leu-8	CEA
				CD14	CD45	CD7		
1. S89-5919	10%	4	9	3	20			
2. S89-5971	36	10	4		4			
3. S89-6499	22	1	1	10	42			
4. S89-6657	10	4	4		18			
5. S89-6671	2	1	7	15	15	10		
6. DM89-3931	2	3	3			10		
7. DM89-4337	15	8	2	2	27	11	53	
8. S89-7418	7	1	1	2	12		73	
9. S89-7438P	4	2	1	2	7	3	46	
S89-7438M	27	21	1	1	44	5	50	
10. S89-7616M	24	17	8	6	36	18	25	
11. DM89-4554	6	3	2	8	20	3	58	
12. S590-329P	7		5		2	40		
S590-329M	3	3	2	2	3	1	2	88
13. S90-580M	4	2	1	1	3	2	45	

FACSscan histograms on this analysis and direct immunocytochemistry of unsorted cell smear.